

### Exercise 1 *The importance of control*

In Section 1.1 in the text-book various purposes of control engineering are listed. For each of the items, give one example of a control system (only a short description is required).

### Exercise 2 *Level control system from the antics*

The weight control system shown in Figure 1 seems to be an automatic bartender. Explain how the control system works.

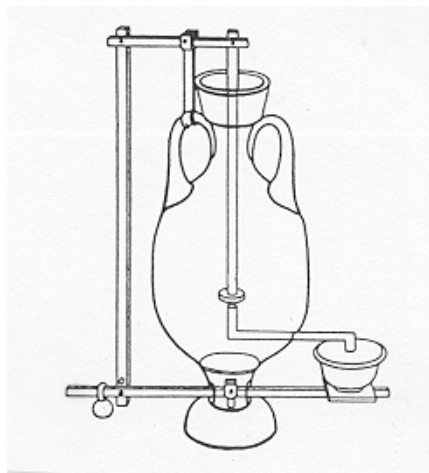


Figure 1: A weight control system from the Antics. An automatic bartender?

### Exercise 3 *Formulating the control problem*

Below are mentioned several processes which are supposed to be controlled. The process output variable is indicated in paranthesis. For each of the processes, what is

- control (manipulating) variable
- disturbance(s) (the main ones)

Also draw a block diagram of the control system.

Make your own assumptions. The processes are as follows:

1. Robot arm or manipulator driven by an electric motor (arm position)

2. Steam heated heat exchanger (temperature)
3. Vessel with dynamic positioning (vessel position), cf. Figure 1.3 in the text-book.

**Exercise 4** *Calculation of the constant control signal in open-loop control*

Figure 2.3 in the text-book shows simulated responses of a dynamic process being controlled by a constant control signal. The static version of the process mathematical model is

$$y = K_u u + K_v v \quad (1)$$

where  $K_u = 1$  and  $K_v = 1$ .

1. As shown in Figure 2.4 in the text-book the static control signal is  $u_0 = 50$ . Use (1) to calculate the static control error to calculate the static control error  $e_s = y_{SP_s} - y_s$  when the setpoint is  $y_{SP_s} = 70$  and the disturbance is  $v_s = -20$ . Is the answer in accordance with Figure 2.3 in the text-book?
2. Derive a formula for the static control signal,  $u_0$ , which can be used to calculate the correct control signal for all static values of the setpoint and the disturbance.
3. Use the formula for  $u_0$  derived in Problem 2 above to calculate the control signal needed for achieving zero control error assuming signal values as given above.
4. Figure 2.6 in the text-book shows the responses in the control system with a PID controller *automatically* calculating the control signal needed to maintain zero steady-state error. Is this control signal value which you can read off the figure equal to the value you calculated in Problem 3 above?
5. Is it better in practice to have an automatic calculation of the control signal (performed by a proper control function) than to manually calculate the control signal value as you did from your knowledge about the process model in Problem 3?

**Exercise 5** *Block diagram of a speed control system*

Figure 2 shows the different components of a speed control system for an electric motor. (The figure is presently unfortunately only in Norwegian version) “Construct” a speed control system by connecting the components.

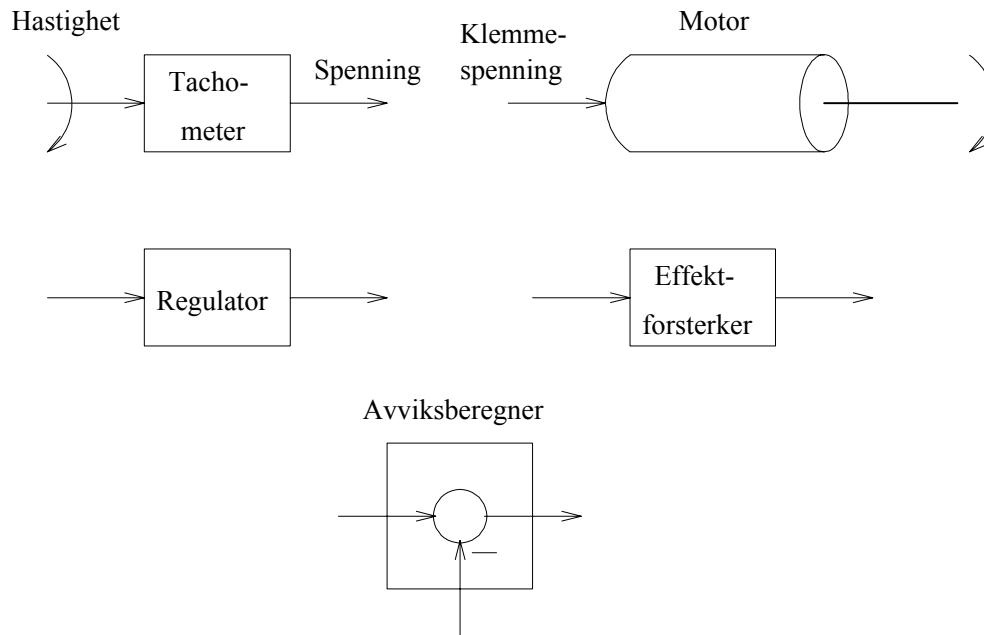


Figure 2: Exercise 5: Various component of a speed control system

**Exercise 6** *From PB to  $K_p$*

What is the value of the controller gain  $K_p$  corresponding to  $PB = 250\%$ ?

**Exercise 7** *From “repeats per minute” to  $T_i$*

Convert 0.2 “repeats per minute” to a value of the integral time  $T_i$

**Exercise 8** *Reduction of control system stability*

Figure 3 shows a temperature control system with two different positions of the temperature sensor. Assume that the temperature controller is tuned so that the stability of the control system is satisfactory with the sensor in position 1.

1. What will happen to the stability if the sensor is moved to position 2?
2. Assume that the sensor is in position 1. How will the stability change if the liquid flow *decreases*?

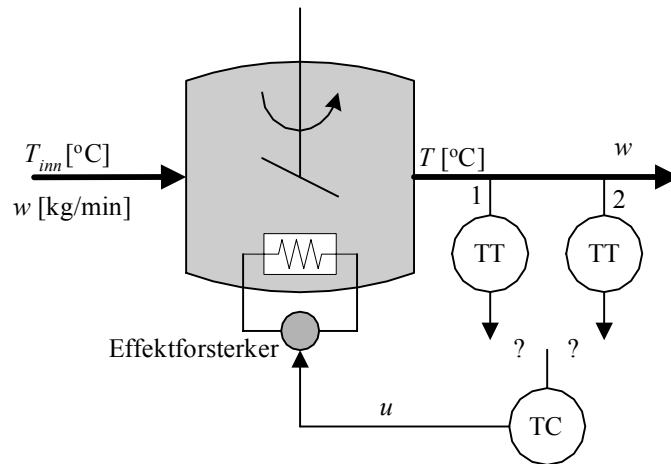


Figure 3: Exercise 8: Temperatur control system

3. How will the stability change if the sensor gain is *increased* (the gain is the ratio of the sensitivity of the measurement signal in volts or amperes to the temperature)?
4. How will the stability change if the heater is substituted by a heater delivering more power per unit of the control signal?

### Exercise 9 *PB and stabilitet*

1. How will the stability of the control loop change if the controller gain  $K_p$  is increased?
2. How will the stability of the control loop change if the proportional band PB is reduced?

### Exercise 10 *Linear interpolation in a gain schedule*

Table 1 shows parts of a gain scheduling based PID controller.

Find  $K_p$  as a function of  $P$  between the operating points shown in the table. The function should be based on linear interpolation.

$GS$	$K_p$	$T_i$	$T_d$
$\vdots$	$\vdots$	$\vdots$	$\vdots$
20%	0.4	5.2	1.3
30%	0.5	4.5	1.6
$\vdots$	$\vdots$	$\vdots$	$\vdots$

Table 1: PID Gain Schedule